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Investigation of RULISON Radioactivity

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INVESTIGATION OF POSSIBLE RESIDUAL RADIOACTIVITY RESULTING FROM THE RULISON NUCLEAR TEST

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FOREWORD

The study reported in this document has been motivated by the public concern throughout the State of Colorado and the nation by the proliferation of man-made radiation. It was felt that a completely independent survey of residual levels would help in forming intelligent public opinion regarding underground nuclear detonations for natural gas stimulation. Kaman Sciences Corporation, a privately owned research corporation, undertook this study completely on its own with no backing or even knowledge of any State or Federal Agency. Because Kaman Sciences manufactures radiation instruments and performs radiation research, it has developed a radiation measuring capability which is unique to the private industrial sector of Colorado. Kaman has also developed the capability of measuring tritium contamination (the only private industrial laboratory in the state which has such capability). Very small amounts of tritium can be detected. If the minimum amount detectable were present in all water used for human consumption, it would cause a radiation exposure to the human body equal to about 1/2000 of the natural yearly level that occurs in Colorado.

Tritium contamination from the flaring of the gas well following the underground nuclear detonation in September 1969 has been the main potential source of radiation from the now famous AEC sponsored nuclear test at Rulison. Because of its tritium measuring capability, and because it has no association with the AEC or any other sponsors of the Rulison test, Kaman felt that it was uniquely qualified to perform an independent assessment of the residual radiation at Rulison. The results and details of this assessment are contained in this document. Briefly, the data show that the radiation safeguards for Project Rulison were sufficiently effective, that no residual radioactivity has resulted from the test. Note that this investigation was carried out some two years after the Rulison event, and the results do not apply to conditions shortly after burst or flaring times.

THE RULISON TEST

The Rulison Test (Project Rulison) was sponsored by the AEC, Austral Oil Company, and the Department of the Interior, as a follow-on to the Project Gasbuggy test in New Mexico in December of 1967. Gasbuggy demonstrated the feasibility of stimulating natural gas flow with nuclear detonations. The nuclear explosion stimulated the production of natural gas from a low-permeability gas-bearing formation by producing a zone of fractured rock and a "chimney" of rock rubble around and above the detonation point. The void spaces thus produced provide a reservoir into which the natural gas flows. A standard gas well is then drilled to the chimney, allowing recovery of the gas. The nuclear device was detonated at a depth of 2570 meters below the ground surface in September of 1969 and chimney reentry and production testing of the well extended from April 1970 through April 1971. During production testing, the gas was burned, or "flared", at the surface. It was during this flaring operation that tritium could have been released to the environment (presumably in the form of water vapor).

SUMMARY OF RESULTS OF THE KAMAN INVESTIGATION

On October 25, 1971, six months after the cessation of test flaring, Kaman monitored the immediate inhabited area around the Rulison site by making wipe tests of oily surfaces (see "Details of Investigation" below), and by checking the radioactivity of water samples. Over 70 different wipe tests and water samples were taken at more than 60 locations. None of these samples showed any detectable radioactivity; i.e., levels significantly higher than background radioactivity. These natural background levels are at least a factor of 100 below the level considered safe by the AEC and by the International Committee on Radiation Protection for uncontrolled areas (Reference 1). The physiological effects of exposure to such levels as these are discussed in Appendix A. It is the opinion of Kaman Sciences, based on the results of this investigation, that Project Rulison had no lasting effect on the radiation environment in the vicinity of the test. This conclusion is based on the fact that none of more than seventy samples indicated any significant activity. The samples were all characterized by very low levels (actually not significantly different than background) and were comparable to the level measured in the Colorado River upstream from the area where the samples of this study were taken, see Table 2. It is highly unlikely that Colorado River water, upstream from the blast site and with its high year-round flow rate, would contain any radioactivity from the Rulison site two years after the shot and six months after cessation of test flaring. This investigation essentially corroborates the AEC sponsored monitoring which was done at the time of flaring, Reference 2, which indicated zero or negligible environmental radiation in the Rulison vicinity.

DETAILS OF INVESTIGATION

A standard method of monitoring for tritium in laboratory facilities is by wipe tests. A wipe test consists of wiping a prescribed area on a given surface with a specially designed wipe paper and then counting the radioactivity of the surface particles clinging to the paper (see Appendix B for counting details). It has been the experience of Kaman Sciences Corporation that surfaces containing oil or grease films tend to concentrate tritium more than other kinds of surfaces and that these retain the tritium much longer than other types of surfaces.

Wipe-test monitoring of surfaces in the vicinity of Rulison had not been previously reported, (Reference 2). Therefore, it seems that if any residual activity were to be found six months after the cessation of production testing, it would likely be found on oily surfaces. Kaman's investigation was aimed primarily at checking such surfaces. Farm tractors and implements provided a convenient source for oily surfaces. Also, because of the general concern about possible water contamination, Kaman monitored several water samples during this investigation. The results of the wipe tests are shown in Table 1 and the water samples in Table 2. The results are listed in net CPM (counts per minute) ± standard deviation and then converted to microcuries per 100 cm^2 for the wipe tests and microcuries per liter for the water samples. The microcurie is defined in Appendix A and the meanings of net CPM and standard deviation are given in Appendix B.

The map, Figure 1, shows the location of each sample taken. The map is a reduced composite of two geological survey maps. The area covered was that closest to the test and included areas downwind from the prevailing high-level southwest wind. Ground level wind pattern is reported to be quite variable, (Reference 2). Therefore, it was felt that proximity to the test was a more important consideration than being downwind from the prevailing high-level winds.

For a radiation-level reference for the wipe tests, the oil film on the crankcase of the automobile used for retrieving the samples was used. Crankcase oil films were the chief source for the wipe tests; hence, a similar source, but one which was not in the vicinity of the Rulison test during the blast or the flaring, was a logical choice. The Colorado River upstream of the area where samples were taken was used as the reference level for water samples, since it should not have been affected by the Rulison experiment. Note in Table 2 that this level was comparable to the other levels.

The counting system at Kaman was checked by obtaining alternate samples with 5 of the ground water samples and with 6 wipe-test samples. These alternate samples were counted by the Radiation Biology Department at Colorado State University. These calibration counts are indicated in the tables. Comparison shows that the calibration count rate adequately verifies the Kaman results.

TABLE 1: WIPE TEST RESULTS

LOCATION (SEE FIG. 1)	SAMPLE NO. (SEE FIG. 1)	NET CPM ± STANDARD DEVIATION	CALIBRATION CPM ± STANDARD DEVIATION*	µCURIE/100 CM²†
TEXACO TANK - 3.5 MILES FROM SITE				
Tank - Around valve	2	1.2±3.78	0±.9	.0000040±.000015
Tank - Valve	3	2.4±3.80		.0000090±.000015
ANNIE H. ESHE, RT. 1 - RIFLE, COLO.				
Tractor Crankcase	4	0±3.67	0±.09	0±.000014
Fordson Tractor Crankcase	5	.2±3.75		
John Deere Grain Binder	6	0±3.66		0±.000014
'40 Chev. Truck Crankcase	7	0±3.72		0±.000015
John Deere Plow Bearing	8	0±3.54		0±.000014
RALPH McDANIEL, RT. 1 - RIFLE, COLO.				
Ford Tractor Gear Box	9	0±3.64		0±.000014
Gas Tank Film	10	0±3.58		0±.000014
DICK SIMMS, RT. 1 - GRAND VALLEY, COLO.				
Ford Tractor Crankcase	11	0±3.65	0±.85	0±.000014
Ford Tractor Gear Box	12	0±3.64		0±.000014
E. A. SCOTT, RT. 1, BOX 181, GRAND VALLEY, COLO.				
Fire wall of School Bus	14	1.2±3.77		.0000040±.000015
Engine Case of Garden Tiller	15	0±3.52		0±.000014
Farmall Tractor Crankcase	16	0±3.60	0±.85	0±.000014
RUSSELL BINGMAN FARM - VACATED				
AC 60 All Crop Harvester	17	0±3.73		0±.000015
John Deere Side Delivery Rake	18	0±3.60		0±.000014
FELIX SEFCOVIC, RT. 1, BOX 69, GRAND VALLEY, COLO.				
John Deere Loader Tractor Crankcase	21	3±3.82		.0000120±.000015
Old Loader Frame	22	0±3.66		0±.000014
Rotor Arm on Massey-Harris Hay Baler	23	0±3.57		0±.000014
JAMES ROGERS, RT. 1, BOX 62, GRAND VALLEY, COLO.				
Bearing on John Deere Van Brunt Grain Drill	24	1.6±3.78		.0000060±.000015
Farmall Loader Tractor Gear Case	25	0±3.57	0±.85	0±.000014
Bearing-Morrill Rake	26	0±3.49		0±.000014
L. W. St.JOHN, RT. 1, GRAND VALLEY, COLO.				
Power Take-off Housing to Smaller of Red Underside Ford Tractor	28	0±3.59		0±.000014
OLIVER WOOD, RT. 1,GRAND VALLEY, COLO.				
Briggs-Stratton Engine - Garden Tiller	29	0±3.60		0±.000014
Rotary Lawn Mower	30	0±3.66		0±.000014
NAME NOT KNOWN, RT. 1, GRAND VALLEY, COLO.				
Ford Tractor Loader-Hydraulic Pump Housing	32	0±3.56		0±.000014
John Deere Hay Baler, Engine Crankcase	33	0±3.70		0±.000014
Case Side Delivery Rake, Adjustment Bearing	34	0±3.62		0±.000014
Roller Bearing on Old Unused John Deere Baler	35	0±3.46		0±.000013
ABANDONED FARMSTEAD, RT. 1, GRAND VALLEY, COLO.				
Bearing on Old Unused Letz Grain Binder	36	0±3.60		0±.000014
W. E. RUGKIN, RT. 1, BOX 80, GRAND VALLEY, COLO.				
Engine Block - Lincoln Welder	37	0±3.67		0±.000014
1 cyl. Engine on Sprayer	38	1.2±3.77		.0000040±.000015
Rear Axle - Ford Tractor	39	0±3.50	0±.85	0±.000014
WILLARD EAMES, RT.1, BOX 43, GRAND VALLEY, COLO.				
John Deere Baler Oil Filter	40	0±3.47		0±.000014
Rear Bearing on John Deere Manure Spreader	41	0±3.43		0±.000013
Wheel Bearing on John Deere Side Rake	42	0±3.63		0±.000014
U-Joint on Ford Power Take-off Mower	43	0±3.48		0±.000014
GLENN St.JOHN, RT. 1, GRAND VALLEY, COLO.				
Crankcase on Case Tractor	44	0±3.66		0±.000014
U-Joint on John Deere Power Take-off Mower	45	0±3.70		0±.000014
Crankcase on 2 cyl. Gas Engine	46	0±3.62		0±.000014
NAME NOT KNOWN, RT. 1, GRAND VALLEY, COLO.				
Crankcase on John Deere Tractor	47	0±3.57		0±.000014
NAME NOT KNOWN, RT. 1, GRAND VALLEY, COLO.				
U-Joint, Power Take-off	48	0±3.48		0±.000014
Oil Drain - Ford Baler	49	.2±3.75		.0000008±.000015
DON BURTARD, RT. 1, GRAND VALLEY, COLO.				
Power Take-off U-Joint on Hesston Wind Rower	50	0±3.55		0±.000014
Crankcase on Ford Tractor	51	0±3.62		0±.000014
DON MOORE, GRAND VALLEY, COLO.				
Oil Filter Gas Engine	53	0±3.54		0±.000014
Grease - Yellow Gear Box	54	0±3.50		0±.000014
Oil From Crankcase of Old Chev. Engine	55	.6±3.76		.0000020±.000015
COLLIN CLEM, RT. 1, GRAND VALLEY, COLO.				
Gear Housing on John Deere Mower	56	0±3.52		0±.000014
Oil Filter on John Deere Tractor	57	0±3.47		0±.000014
Crankcase on Old McCormick-Deering Farmall	58	2.8±3.82		.0000110±.000015
ABANDONED FARMSTEAD				
Clutch Housing on Unused Tractor	59	0±3.69		0±.000014
G. A. KNIGHT, GRAND VALLEY, COLO.				
Gus Trailer Differential	60	0±3.52		0±.000014
Transmission of Old Allis Chalmers Tractor	61	0±3.57		0±.000014
EDWARD FORSHER, GRAND VALLEY, COLO.				
Crankcase of Old McCormick-Deering Tractor	62	0±3.65		0±.000014
Gear Housing of Forge Blower	63	0±3.68		0±.000014
A. J. HOAGLAND, RT. 1, GRAND VALLEY, COLO.				
Flywheel on Housing of John Deere Tractor	65	0±3.51		0±.000014
Hydraulic Pump Housing on Gas Trailer	66	0±3.61		0±.000014
Engine Block on John Deere Tractor w/Loader	67	0±3.52		0±.000014
Filter on Fuel Tank	68	.8±3.76		.0000030±.000015
STANDARD-OIL FILM FROM CRANKCASE OF KAMAN CAR*	--	0±3.63		0±.000015

* The wipe used as the reference standard has an activity comparable to all others taken. This is the background level of 0.00012 µcurie/100 cm². See footnote of Table 2.

† Recommended maximum is 0.00112 µcurie/100 cm² above normal background for uncontrolled areas.

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TABLE 2: WATER SAMPLE RESULTS

LOCATION (SEE FIG. 1)	SAMPLE NO. (SEE FIG. 1)	NET CPM ± STANDARD DEVIATION*	CALIBRATION CPM ± STANDARD DEVIATION**	μCURIE/LITER ± STANDARD DEVIATION†
BATTLEMENT CREEK, APPROX. 2 MILES FROM BLAST SITE				
Battlement Creek	1	1±3.66		.013±.06
DICK SIMMS, RT. 1, GRAND VALLEY, COLO.				
Spring Water	13	3.40±3.73	-.61±.68	.04±.05
RUSSELL BINGMAN, GRAND VALLEY, COLO.				
Spring Water	19	0±3.44		0±.045
ABANDONED FARMSTEAD				
Stagnant Ground Water	20	0±3.61	.33±.68	0±.048
L. W. St.JOHN, RT. 1, GRAND VALLEY, COLO.				
Stagnant Water in Lava Pond - Fed from Creek	27	0±3.53		0±.048
OLIVER WOOD, RT. 1, GRAND VALLEY, COLO.				
Running Ground Water	31	0±3.62	1.64±.69	0±.05
DON BURTARD, RT. 1, GRAND VALLEY, COLO.				
Water from Burtard Residence	52	4.20±3.75	.91±.69	.06±.05
EDWARD FORSHER, GRAND VALLEY, COLO.				
Water Drainage Off East Side of Morrisania Mesa	64	0±3.56	.25±.68	0±.045
RULISON BORDER, BRIDGE AT RULISON NEAR U. S. HIGHWAY 6				
Colorado River	69	0±3.46	.46±.68	0±.045

* Net CPM (counts per minute) is determined by subtracting from the counts of the sample, the counts produced in the counting system, by a "blank sample" known to be essentially free of radioactive substances. These latter counts are called the "laboratory background counts". Sample No. 69 from the Colorado River was taken to serve as a reference "background" for the Rulison area. Zero net counts for this river sample means that the Colorado River sample gave essentially the same count rate as Kaman's laboratory "blank sample".

** Calibration counts were provided by Professor Keith Schiager, Dept. of Radiology and Radiation Biology, Colorado State University.

† Recommended maximum is 3 μcurie/liter above normal background. Normal background for this area is 0.001 μcurie/liter.

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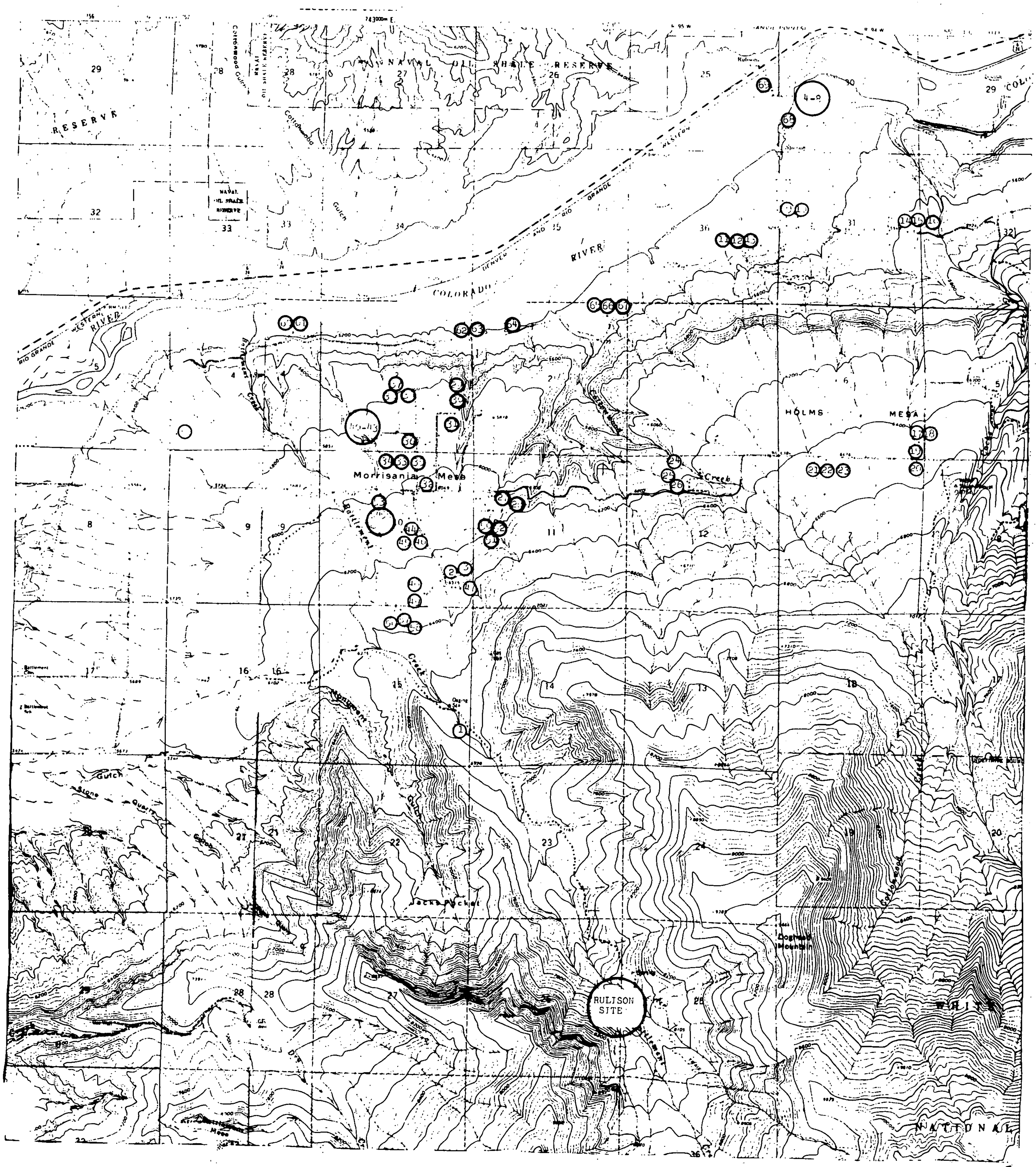

FIGURE 1

RULISON AREA SHOWING LOCATION OF SAMPLES TAKEN

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APPENDIX A

RADIATION: BIOLOGICAL EFFECTS AND EXPOSURE CONTROLS

A great deal has been written about the biological effects of radiation. The reader is directed to References 3 and 4 for detailed descriptions. The purpose of this Appendix is to summarize briefly the effects as known and how they relate to the study reported in this document.

The injury inflicted on the body by radiation is due to energy absorbed by the body from the incident radiation. Hence, the radiation dose is measured in terms of an energy absorption unit, the "rem", (an acronym for "Roentgen equivalent man") or the millirem (mrem) which is a thousandth of a rem. The amount of "rems" delivered to the body depends on the type of radiation, (i.e., whether alphas, betas, or gammas) and on the energy of the individual particles, or "rays". In general, the more energetic the radiation, the more penetrating and hazardous it is. Researchers have established the maximum number of rem of exposure to which the human body or given parts of the body can be subjected without apparent injury. The greatest chance for radiation damage to the body occurs when a given radioactive substance is taken into the body (ingested).

Tritium, the radioactive substance of concern in this study, can be hazardous because of the ease with which it is ingested. Tritium emits a very low energy beta particle, hence, the radiation itself is a very mild one. Tritium exposure limits are determined by considering the amount of radioactivity contained in the body water. Radioactivity is measured by the rate of emission of radioactive particles or rays which occurs with each disintegration of a radioactive isotope. The common unit is the microcurie (μci) which is 37,000 disintegrations per second. The National Committee on Radiation Protection

(NCRP) has determined that the maximum safe level for tritium found in the water of the body is 28 microcuries per liter. The activity level of all water samples checked in this study fell far below this value by a factor of several hundred. Therefore, if the body water contained the same amount as that checked in this study, it would still fall extremely far below that considered harmful.

Soon after the discovery of X-rays and naturally occurring radioactivity in the 1890's, it became evident that exposure to such radiation could be harmful. This evidence led to the establishment in the 1920's of the National Committee on Radiation Protection (NCRP) and the International Commission on Radiation Protection (ICRP) for the purpose of defining safe exposure limits to individuals. Their first official recommendations were published in 1931 with revisions following in 1934 and 1936. Prior to World War II, very few people were involved with radiation. However, the development and utilization of the atom bomb and nuclear reactors beginning with World War II vastly increased the number of people working with and exposed to radiation. There is no evidence to date of any injury resulting from exposures of individuals to radiation levels which do not exceed the 1936 figure (Reference 3). Such a record is indeed impressive considering the small amount of data on radiation injury which was available in 1936.

Considerable research is still being conducted regarding the harmful effects of radiation and regarding the appropriate limits which should be set on individual exposures. The general public has recently been made aware that there is a divergence of opinion among the researchers in the field about the harmful effects and the appropriate limits of exposure.

With such a controversy among the nation's experts, it may seem to the layman that evaluating his own personal risk is a hopeless task. The task is really not hopeless, however. The reason that anyone can do reasonably well in evaluating his own risk is because he can compare any radiation exposure to that which he receives from natural background radiation. Background radiation is essentially unavoidable, and each individual and all of his ancestors have been exposed to it all their lives. Background radiation comes from cosmic radiation (radiation from outer space) and from radioactive substance occurring naturally in soil. Cosmic radioactivity varies with elevation, simply because there is less air shielding at higher altitudes. The overall cosmic dose is about 35 mrem/per year at sea level and about twice that at a one-mile elevation. Radioactivity from the soil (usually called the terrestrial source) varies greatly with the locale. The average soil in the U.S. produces an annual dose to residents of about 60 mrem. That at Denver, Colorado, however, is about 130 mrem. Colorado residents are exposed to a high background radiation both because of the soil dose and the high cosmic dose due to high elevation. Total annual background dose to Denver residents is 200 mrem, while the average in the U.S. is about 100 mrem.

The lay person can easily compare any dose to which he may be exposed to his exposure from natural background radiation and to fluctuations in natural background exposure. For example, if he is involved in a profession which exposes him to 20 mrem per year, he could look upon it as being 1/10 of the natural background dose he would receive as a resident of Denver, Colorado, or 1/5 of the added dose per year he would receive if he moved, say, from St. Louis to Denver. Consideration of background radiation gives every individual an understandable frame of reference upon which he can build his own conception of what a given dose of radiation might do to him. It then becomes analogous to his evaluating his risk of suffering a traffic accident in using the highways, or of his risk of injury in accepting a given type of employment, such as in a mine or a factory.

Background levels are always measured and subtracted from all experimental readings in order to determine that net amount caused by the effect being studied. Hence, the comparison is always an easy one. In the case of this study, with all readings essentially indistinguishable from background, there is really no choice but to make a comparison with background. However, any assessment of radiation exposure can be made on the basis of comparing to natural background. By comparing to natural background and to the maximum exposure levels recommended by the National Committee for Radiation Protection (NCRP), the lay person can assess his own radiation hazard. Note that the Tables 1 and 2 of this document indicate the appropriate maximum levels recommended by the NCRP.

APPENDIX B

COUNTING PROCEDURE

The samples taken at Rulison were counted in Kaman Sciences liquid scintillation counting facility. The components of this facility are listed by manufacturer and model number in Table B-1.

TABLE B-1

COMPONENTS OF LIQUID SCINTILLATION COUNTING SYSTEM

COMPONENT NAME	MANUFACTURER	MODEL NO.
Liquid Scintillation Fluid	J. T. Baker Chem. Co.	---
Photomultiplier Tubes	Dumont	#6292
Preamplifier	Canberra Industries	#817
Single Channel Analyzer	Canberra Industries	#817
Scalers	Ortec	#484

The scintillation counting procedure is well described in published literature (see for example References 3 and 5). Briefly, the process involves the excitation by radiation of the electrons surrounding certain types of atoms called "phosphors". These phosphors de-excite by emission of a light pulse. These light pulses energize a photomultiplier tube which converts the light flash to an electrical pulse which is used to indicate the incident radiation which triggered the process.

Use of a liquid scintillator greatly enhances the counting efficiency for counting radioactive material whose radioactivity is in the form of low energy emissions. Such low energy particles or rays would not penetrate sufficiently into a solid scintillator to give a good signal. However, by dissolving or mixing the radioactive substance within the liquid scintillator itself, strong scintillation signals are assured.

The count rates of the samples analyzed are used to determine the radioactivity of the samples by comparing to the count rate of a standard whose absolute radioactivity has been accurately established. The activity of the sample counted is then determined by the following formula:

$$\text{activity of sample} = \frac{\text{net count rate of sample (CPM)}}{\text{net count rate of standard (CPM)}} \times \text{(activity of standard)} \qquad \text{(B-1)}$$

With all samples counted the scintillation pulses are "quenched" in varying amounts. Quenching is attenuation of the light pulse produced by the radioactivity and affects the count rate determined for the sample. The variation in quenching from sample to sample must be accounted for to obtain an accurate measure of the sample radioactivity. This variation is compensated for by first counting the sample, then adding to the sample a known amount of activity, and counting the sample plus this known activity together. By subtracting the counts of the sample being analyzed from the sum of the known standard plus the sample, a valid means of accounting for the quenching effects of the individual sample is afforded. The process effectively produces the same quenching effect in the counts of the standard as it does in the counts of the sample being measured. The appropriate radioactivity, accounting for the quenching effect on the count rate is then

$$\text{activity of sample} = \frac{\text{net counts of sample} \times \text{activity of standard}}{\text{net counts of known radioactive standard + sample - counts of sample}} \qquad \text{(B-2)}$$

A quenching effect, particularly of wipes of greasy surfaces, is found in nearly all samples. This effect was checked for the samples of this study by using Equation B-2.

In Tables 1 and 2 the values of interest are listed with a "± Standard Deviation". This is necessary to account for the fact that radioactive emissions are random events and hence, subject to statistical variation. Standard deviation is a measure of the statistical variation one might expect from different measurements of some statistical phenomenon (i.e., one governed by random events). Thus, in listing some measure, as for example, 10 ± 5, the number 10 is the measured quantity, ± 5 is the standard deviation. Standard deviation gives the range in which one half of a given set of measurements of the same phenomenon are expected to fall. In the example above, half of a set of measures of the same thing would be expected to fall between 5 and 15 and half outside this range. Any textbook on statistics will provide the reader with greater detail on this subject if he wishes to pursue it.

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The effectiveness of a scientific organization is a function of the scientific abilities of the individual members, the vigor with which these members attack technical problems, and the environment in which they work.

Kaman Sciences Corporation has realized a high degree of effectiveness by employing the highest caliber and most productive minds, by properly organizing and channeling their capabilities so that timely and successful solutions to scientific problems are assured, and by providing a scientific atmosphere which is essentially free of administrative burdens.

The combined background and experience of the staff provide capabilities over the entire range of engineering problems, beginning with fundamental research, conception, feasibility and design, and extending through testing, production, operational use and evaluation.

Kaman Sciences is large enough that many different disciplines may be brought to bear on a particular problem. At the same time, it is of such a size that the efficiencies inherent in a small, well organized group are realized. This philosophy of using flexible, balanced and fast-moving project teams to solve technical problems has repeatedly demonstrated its value, and is reflected in the steady growth of the organization.

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